Investigation of Cavities and Craters Formed as the Result of Nuclear Explosions for the Purpose of Solving the Problem of the Earth Protection against the Near-Earth-Objects

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The possibility of the Earth collision with the Near-Earth-Objects (NEO) necessitates searching for methods of influencing the NEO which could help to prevent this threat. In the materials of the Conference held in Snezhinsk late in September 1994 and dedicated to this problem we can find different proposals for solution of this problem [1]. From among them there is a proposal on nuclear device delivery to the NEO, and the nuclear explosion at the NEO. This could enable to achieve the following:

— disintegrate the NEO into fragments of dimensions necessary for providing their burning in the Earth's atmosphere;
— disintegrate the NEO into fragments and alter their trajectory in order to miss the Earth;
— alter trajectory of the NEO as a whole by transferring a certain momentum to it.

Selection of a certain method of acting will be the content of a specific project and will depend on specific circumstances, but even now we need to carry out calculations and experimental research to reveal those aspects of the future project that to the largest extent will influence the selection of the specific method. In other words, even now, without waiting for the impending terrible menace we must do research results of which are necessary for implementing the project of preventing this catastrophe. During one of the presentations in Snezhinsk one of the authors of this paper gave rather convincing reasons proving that even now we have sufficient means for implementing the project of the Earth protection against the NEO [2]. But availability of the means is the necessary but not sufficient condition for implementation of such project. The project can't be considered acceptable if it contains a high uncertainty of assessing effectiveness of its implementation which eventually will depend on effectiveness of nuclear explosion interaction with the NEO.

The theory, calculations, and experience of nuclear explosions under terrestrial conditions show that effectiveness of the nuclear explosion influence on a certain object or ground is determined not only by energy release of the nuclear device and position of the nuclear explosion center with respect to the surface, but also by characteristics of the material subject to the nuclear explosion effect: its density, strength, equation of state.

The nuclear explosion acting on the NEO must take place far from the Earth [2], but the process of the explosion energy transfer to the NEO will be the same as on the Earth, i.e. either by the explosion radiations (x-ray and/or neutron), or at direct contact between the nuclear device and the NEO, or with the nuclear device buried in the NEO. In any of these three cases of the NEO interaction with the nuclear explosion we need to know the properties of the NEO matter. Despite of the rather detailed classification of the asteroids and comets by the types of the substances composing them [3], this classification should be considered as a tentative during assessing the effectiveness of a certain method of applying the nuclear explosion (explosion at some altitude, surface explosion, or buried explosion). As we know accuracy of these estimates to the largest extent depends on the pressure range under consideration. Up to 400 kbars the processes of terrestrial ground behavior are well described in calculations, as well as shock propagation in it. The pressure range from 400 down to 100 kbars is characterized by a rather complex behavior of substances, practically different for each substance because of the phase transitions. Therefore, it is difficult to describe it with the calculations. With pressure decrease in the shock wave the strength begins to play larger role. This necessitates to take into account the deviator of stresses and strains which is not the same for material samples and for the same material *in-situ*. Though Academician M. A. Sadovsky and his disciples showed that the process of rock fragmentation follows the same laws regardless of the place where these rocks are located, on the Earth or beyond it, prediction of a specific sample fragmentation (whether it is a too large sample formed during explosion in a rock drill hole or a separate rock that must be withdrawn from a future highway) is always a complicated task that is more often solved practically but not with calculations. Besides that, our experience of nuclear explosions both under the ground and above it is referred to terrestrial conditions when interaction between the nuclear explosion and the ground takes place under conditions of the Earth's atmosphere and the Earth's pull. For the case of asteroid or comet these conditions will be quite different, and this must be taken into account. The above mentioned brings us to the only conclusion: prediction of the NEO behavior after its affecting with nuclear explosion is an extremely complicated and crucial task.

Certainly, many problems could be removed if we could investigate different asteroids using space sondes or bring to the Earth the ground samples from asteroids. At the above mentioned conference in Snezhinsk, Professor Teller proposed as an alternative or complementary to such research to perform a nuclear explosion at some asteroid, and to investigate its effect on the asteroid. But both the space investigation of the asteroids and the nuclear explosion at the asteroid are hardly possible in the nearest future. At the same time there are thousands of horizontal and vertical holes on the Earth in which the underground nuclear explosions were conducted. Most of these explosions were contained, but a small number of them were cratering explosions. Rocks surrounding the cavities of the both types of the explosions still preserve the traces of the nuclear explosions. These effects were investigated in the USA, in the USSR, and France. Some results of this research have been published [4]. Comparison of the results of investigating the explosion cavities and the surrounding rocks with results of numerical calculations showed that these results describe very well behavior of different soils during the nuclear explosion under terrestrial conditions. We believe it is interesting to continue this work since the research which has been carried out has covered a relatively small number of the terrestrial ground types. Continuation of this research could yield calibration of computer methods at large number of different ground types, and by that to improve their validity essentially.

Preliminary study of the experience of investigating the explosion cavities in the mountain-mass Degelen at the former Semipalatinsk nuclear test site shows that the preferable method is excavation of holes towards the place in the adit the investigator is interested in. Despite of the fact that the mountain-mass Degelen is composed of primarily strong (10-12 points by the Protodyakonov's scale) rocks, excavation of the holes in them is not a problem. We might be interested in not only the part of the rocks directly external to the explosion cavity, but also in the zones of fragmentation and fracturing, as well as the zones of collision between the contrary shocks from several explosions carried out in one adit with time interval of several milliseconds. Character of the rock fragmentation in such collision zones may significantly differ from the character of fragmentation in the fragmentation zones which are formed during propagation of one shock.

Direct study of the rock state in various zones around the cavity of a certain explosion can be complemented with various geophysical methods: seismic sounding, gravimetrical and magnetic measurements, study of radionuclide migration.

It is evident that to do this work the efforts of one country won't be enough. We propose to unite in the international project the efforts of scientists and engineers of the five nuclear states and Kazakhstan the territory of which (the mountain-mass Degelen) has several hundreds of adits where in the end boxes the nuclear explosions were conducted. Besides that, there are several craters from the cratering explosions. The cavities of these explosions haven't been opened. Within the framework of the proposed international project we could:

- investigate the cavities of the nuclear explosions;
- investigate the zones of fragmentation and fracturing;
- carry out calculations and compare their results with the results of investigating the cavities, the zones of fragmentation and fracturing;
- on the basis of the work done develop the calculation method for different nuclear explosion effects upon ground at various position of the explosion epicenter with respect to the surface of the asteroid or comet.

We estimate the cost of the full complex of the geophysical research at the Degelen mountain-mass as $4 mln. U.S. Someone may think this sum is too large, but to our mind, this work in a short time could yield creation of method for engineering calculations for future projects of nuclear explosion effect upon the NEO. We don't know how much time we have therefore we mustn't waste it. Just now we need to lay the basis for implementing the project "The Earth against the NEO".

References

The International Conference "Space Protection of the Earth against the Near-Earth-Objects (SPE-94)", Snezhinsk (Chelyabinsk-70), Russia, September 26-30, 1994, Abstracts of Papers, Part I and II.

Litvinov, B. V., "On the System of the Earth Protection against the Near-Earth-Objects, and Role of Nuclear Devices in It". Presentation at the International Conference "Space Protection of the Earth against the Near-Earth-Objects (SPE-94)", Snezhinsk (Chelyabinsk-70), Russia, September 26-30, 1994.

Asteroids II, Binzel, Richard P., Gehrels, Tom, and Mathews, Mildred Sharpley, editors with 100 collaborating authors. The University of Arizona Press. Tucson. 1989.

Peaceful Nuclear Explosions, Proceeding of a Panel Vienna, 2-6 March 1970. IAEA. Vienna. 1970.